Reinforcement learning

Episode 0

Introduction to reinforcement learning

Yandex
Data Factory

LAMBDA

British Hedgehog
Preservation Society

Terms

- **Ask**!
  - Even if the question feels stupid.
  - Chances are, half of the group is just like you.
  - If it's necessary, interrupt the speaker.

- **Contribute!**
  - Found an error? Got useful link? Ported the seminar to py3 from py2? Answered peer's question in the chat?
  - You're awesome!

<a convenient slide for public survey>

Supervised learning

Given:

- objects and answers (x, y)
- algorithm family $a_\theta(x) \rightarrow y$
- loss function $L(y, a_\theta(x))$

Find:

$$\theta' \leftarrow argmin_\theta L(y, a_\theta(x))$$

Supervised learning

Given:

- objects and answers (x, y)

[banner,page], ctr

- algorithm family $a_\theta(x) \rightarrow y$

linear / tree / NN

- loss function $L(y, a_\theta(x))$

MSE, crossentropy

Find:

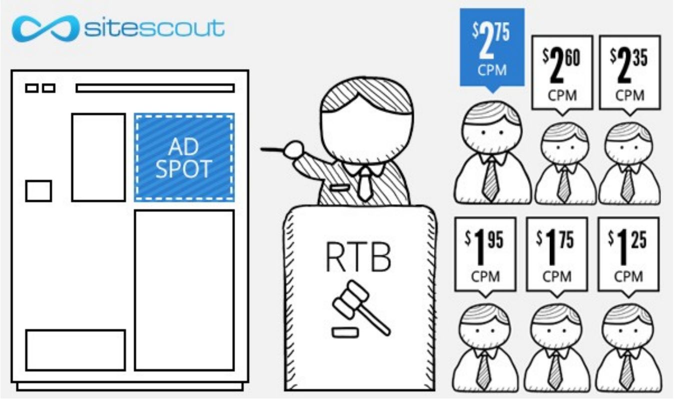
$$\theta' \leftarrow argmin_\theta L(y, a_\theta(x))$$

Supervised learning

Great... except if we have no reference answers

Online Ads

Great... except if we have no reference answers



We have:

- YouTube at your disposal
- Live data stream
  (banner & video features, #clicked)
- (insert your favorite ML toolkit)

YouTube
YouTube
YouTube

We want:

- Learn to pick relevant ads

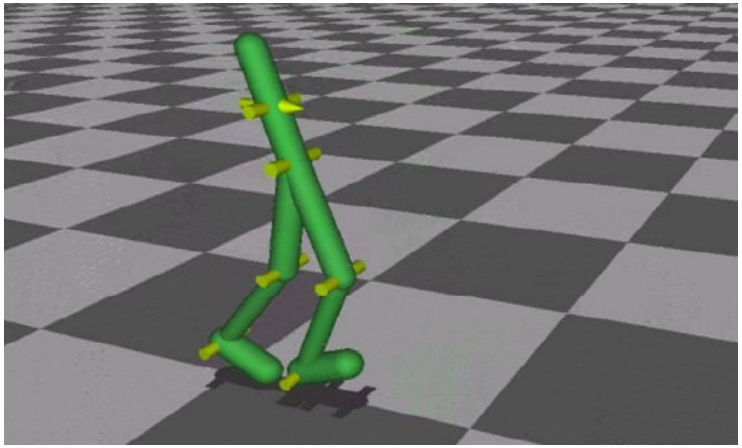
Ideas?

Giant Death Robot (GDR)

Great... except if we have no reference answers

We have:

- Evil humanoid robot
- A lot of spare parts to repair it :)

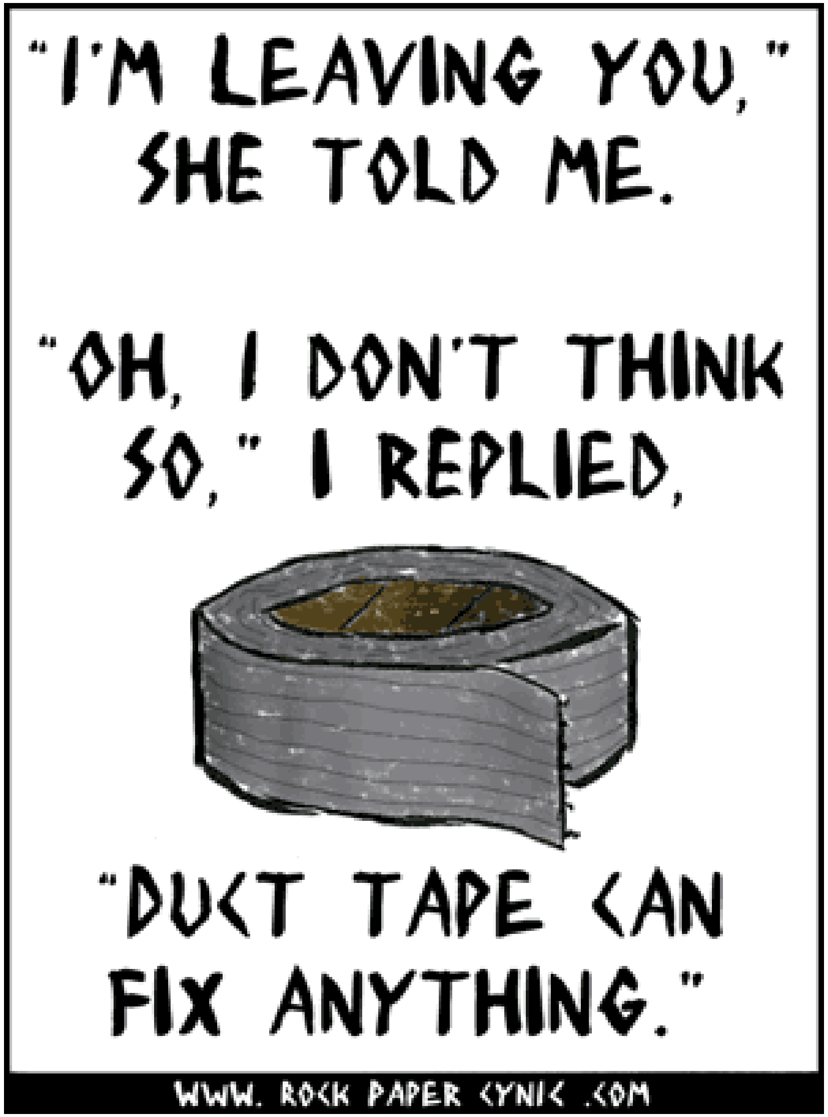


We want:

- ~~Enslave humanity~~
- Learn to walk forward

Ideas?

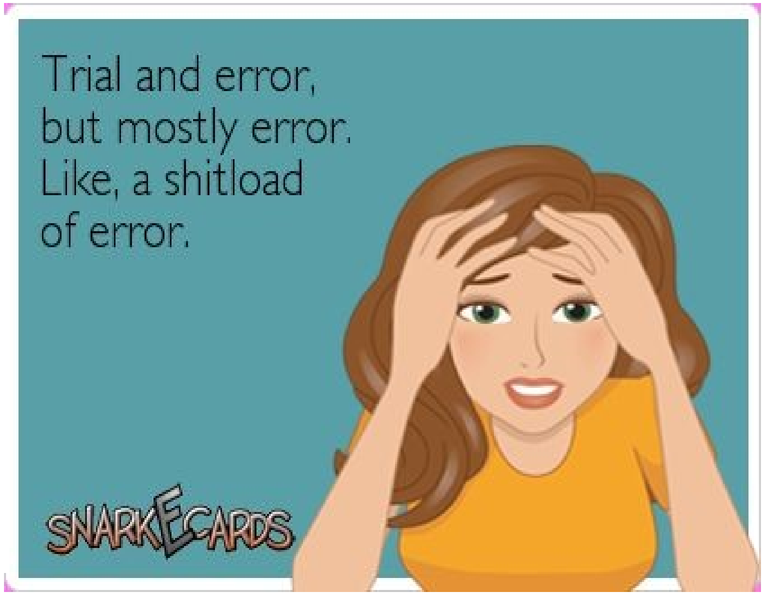
Duct tape approach


"I'M LEAVING YOU," SHE TOLD ME.
"OH, I DON'T THINK SO," I REPLIED,
"DUCT TAPE CAN FIX ANYTHING."
WWW. ROCK PAPER CYNIC .COM

Duct tape approach

Common idea:

- Initialize with naïve solution
- Get data by trial and error and error and error and error
- Learn (situation) → (optimal action)
- Repeat



Duct tape approach

Problem 1:

- What exactly does the “optimal action” mean in the Giant Death Robot setting?

Push yourself forward as far as you can at each tick

VS

Do what allows you to walk farther over next N seconds

Duct tape approach

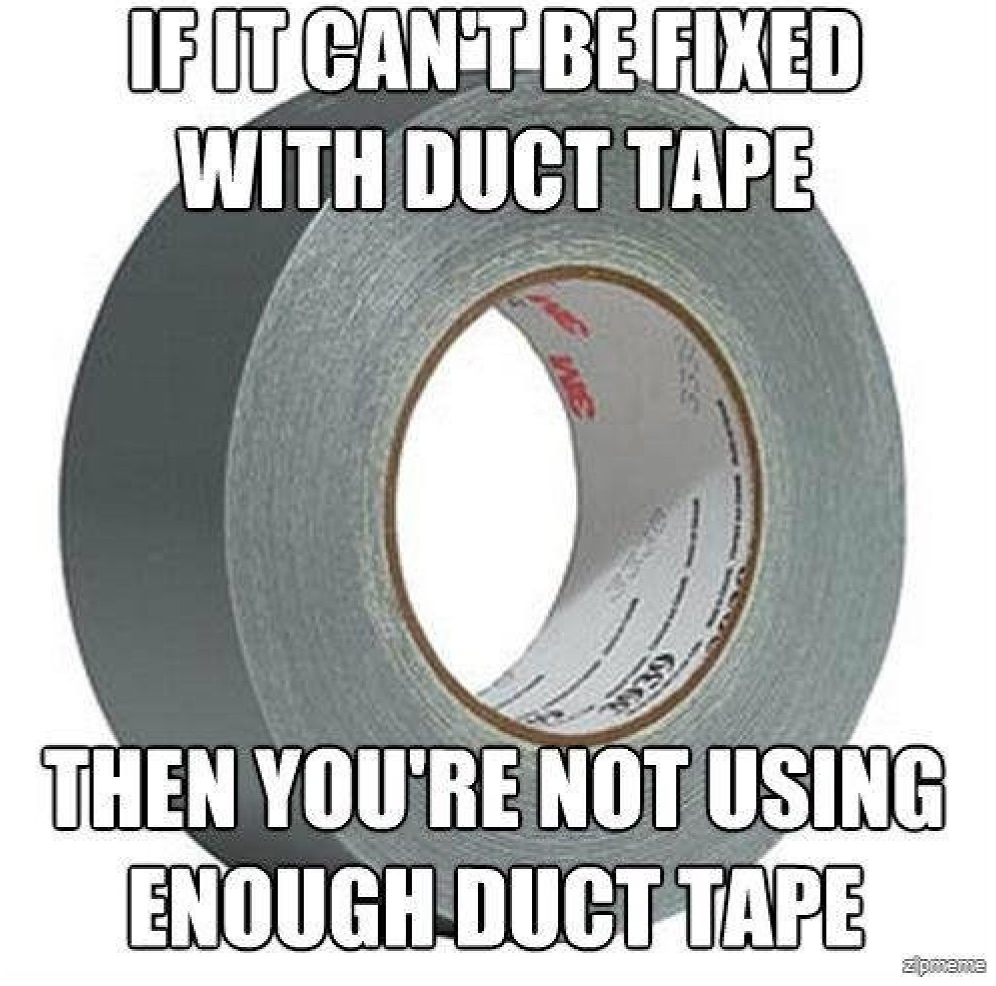
Problem 2:

- If you only act by the “current optimal” policy, you may never hit the global optimum.

- If your learned to fall down and crawl forward, that it will never get examples of how to walk because it always crawls.

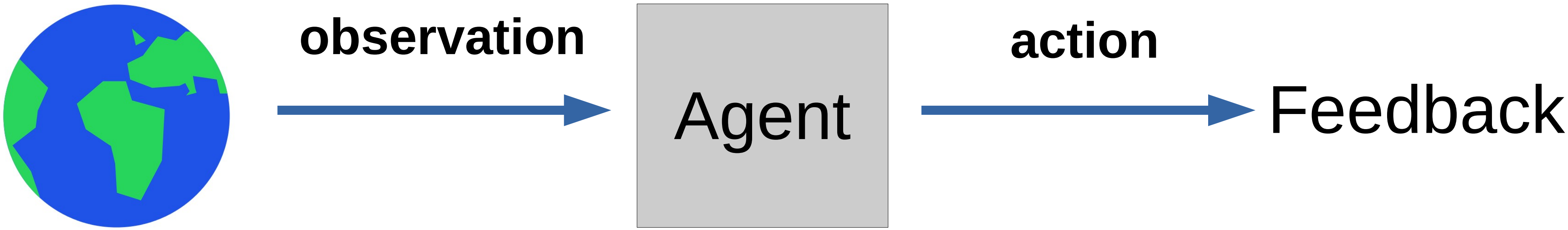
- **Ideas?**

Duct tape approach



What is: reinforcement learning

What is: bandit



observation

Agent

action

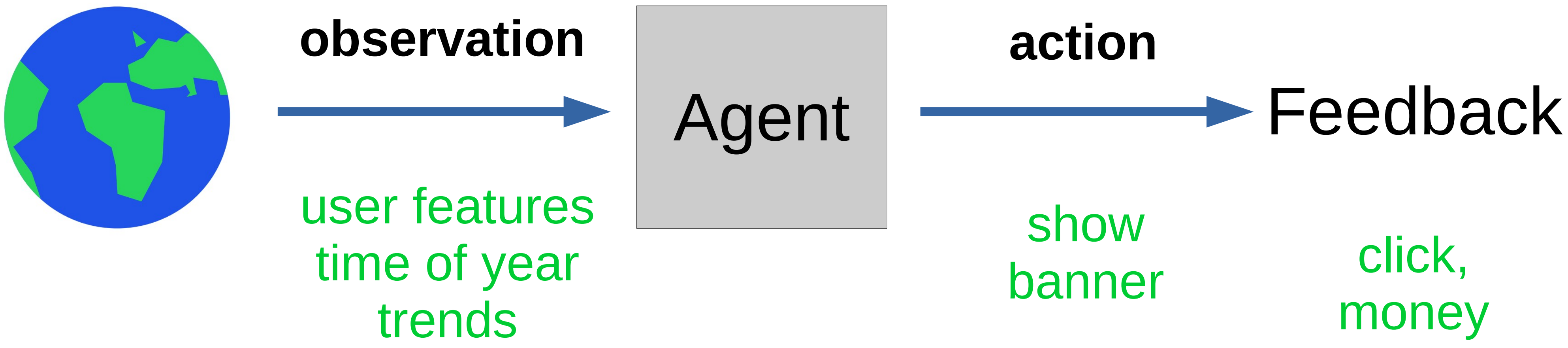
Feedback

Examples:

- banner ads (RTB)
- recommendations
- medical treatment

Trivia: what's observation, action and feedback in the banner ads problem?

What is: bandit



observation

user features
time of year
trends

Agent

action

show
banner

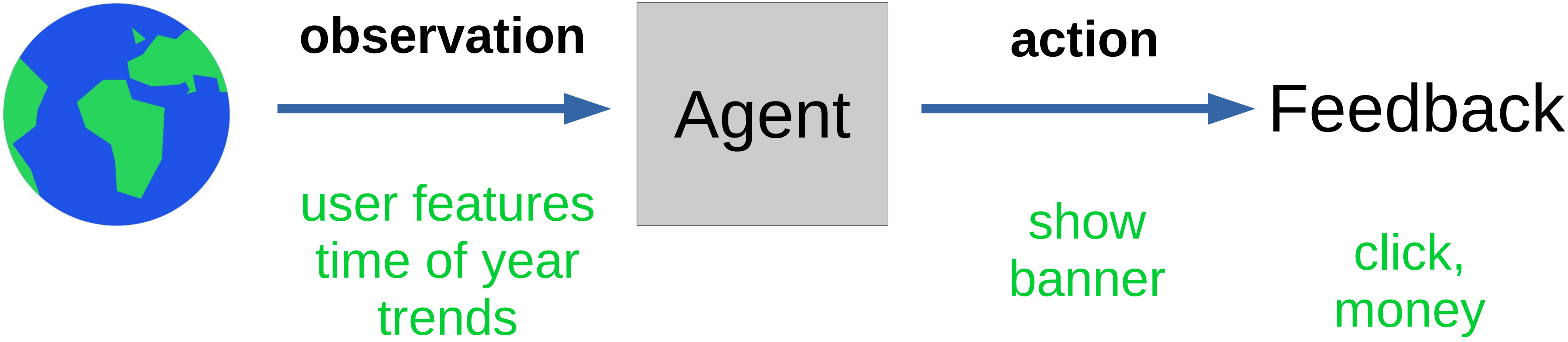
Feedback

click,
money

Examples:

- banner ads (RTB)
- recommendations
- medical treatment

What is: bandit



observation

user features
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Agent

action

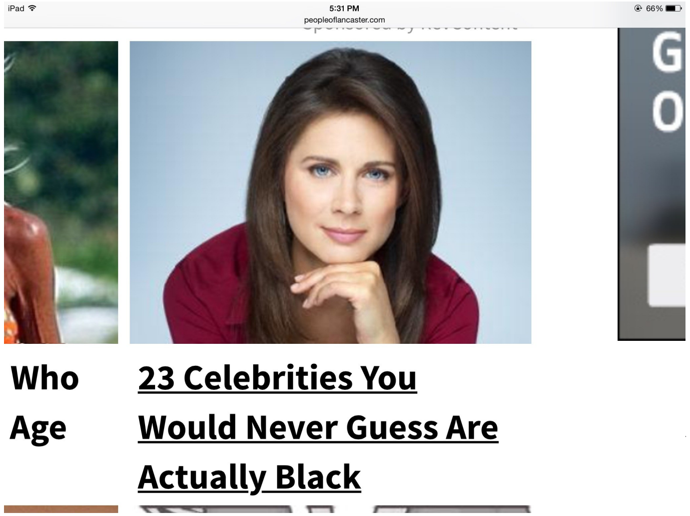
show
banner

Feedback

click,
money

Trivia: You're Yandex/Google/Youtube. There's a kind of banners that would have great click rates: the “clickbait”.

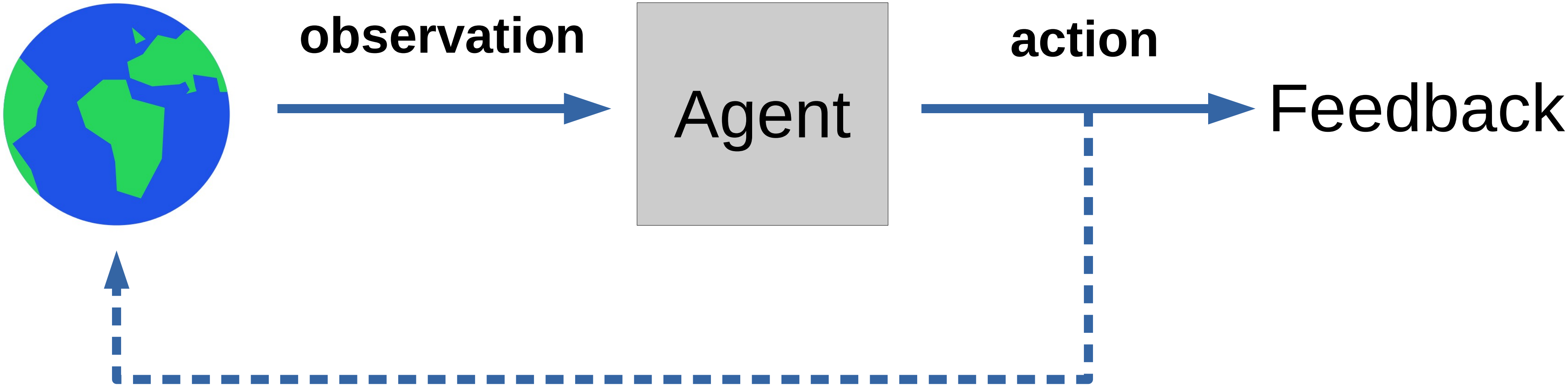
Is it a good idea to show clickbait?



Who Age

23 Celebrities You Would Never Guess Are Actually Black

What is: bandit



observation

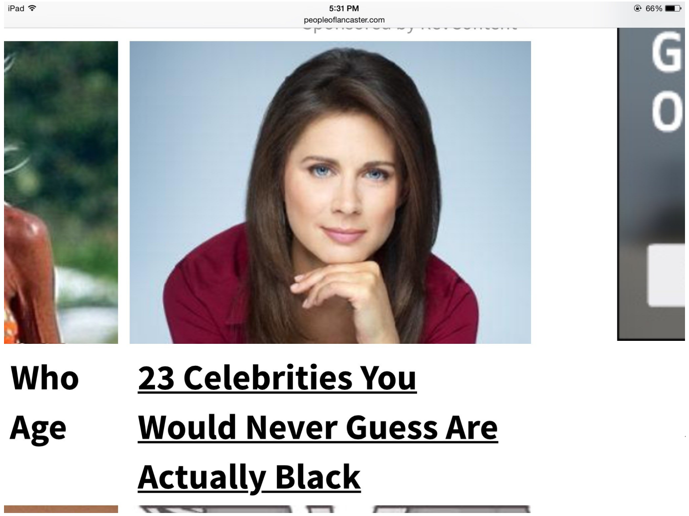
Agent

action

Feedback

Trivia: You're Yandex/Google/Youtube. There's a kind of banners that would have great click rates: the “clickbait”.

Is it a good idea to show clickbait?
No, noone will trust you after that!



Who Age

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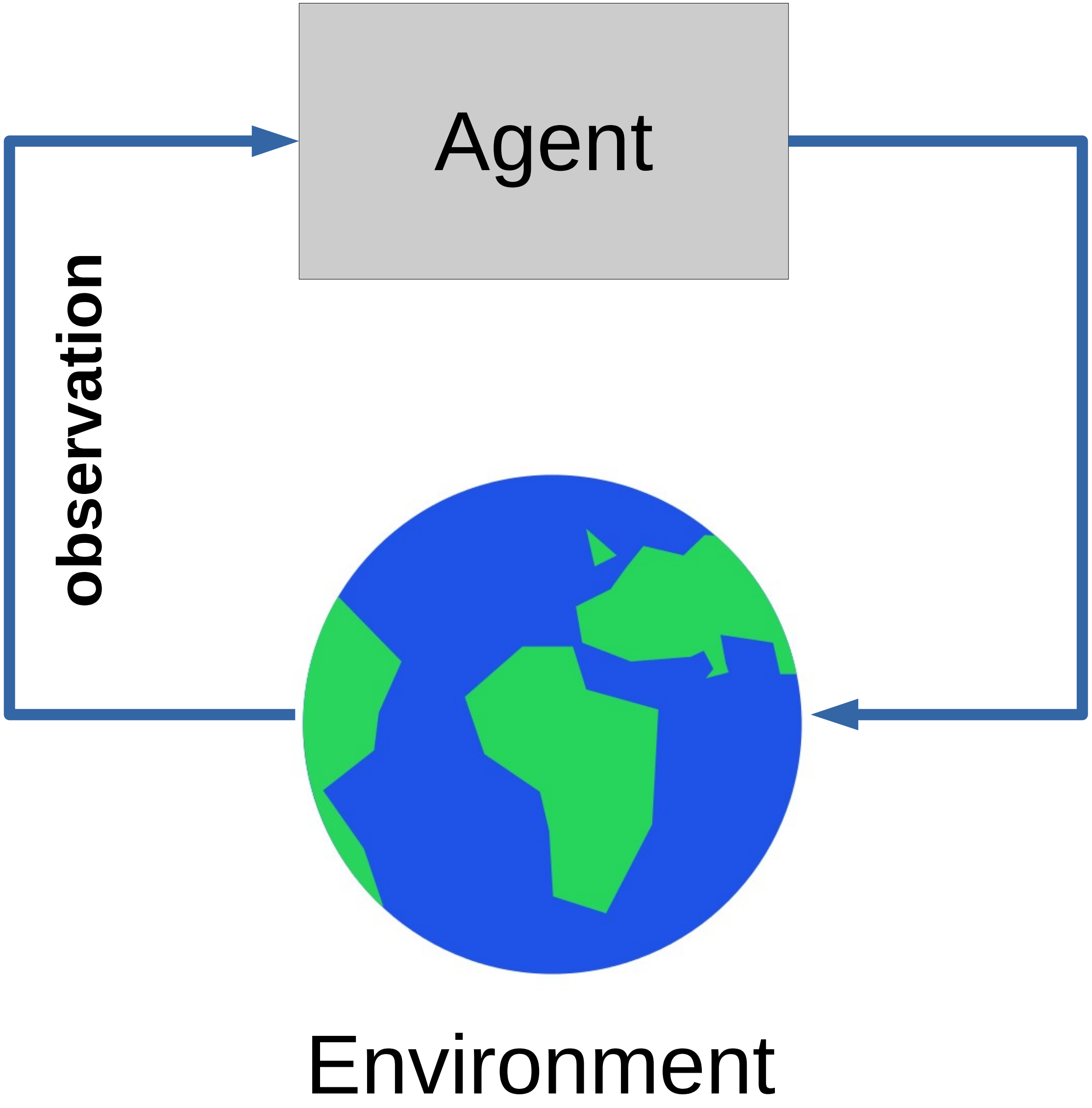
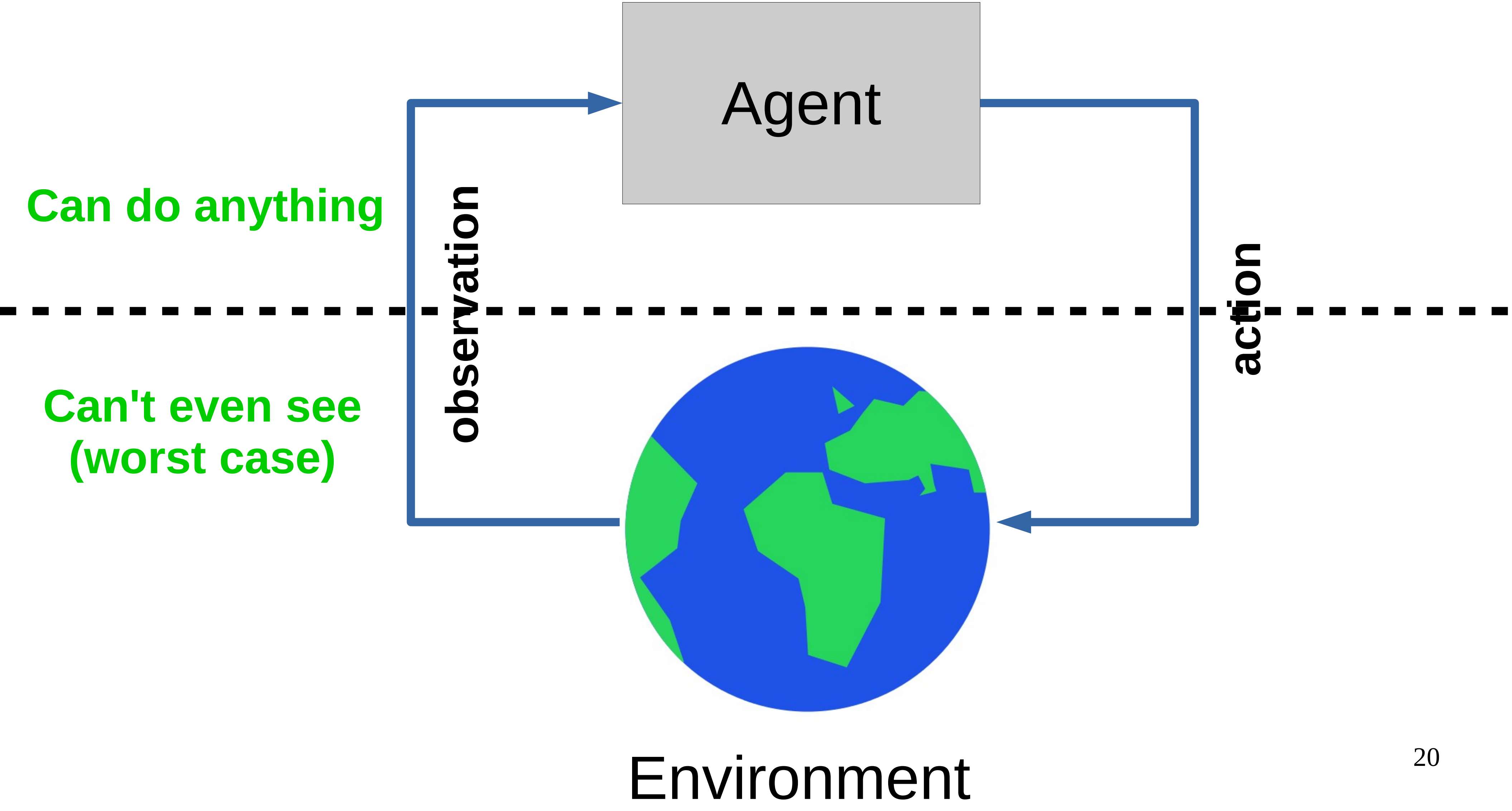
What is: decision process



What is: decision process



Agent

observation

action

Environment

Can do anything

Can't even see
(worst case)

What is: reinforcement learning

- Agent interacts with environment
  - site interacts with user
  - robot interacts with the physical world

- Feedback on agent performance
  - Agent receives feedback on **his** performance
  - Usually a real number (more=better)

What is: reinforcement learning

- Agent interacts with environment
  - site interacts with user
  - robot interacts with the physical world

You get to pick actions, not just observe data

- Feedback on agent performance
  - Agent receives feedback on **his** performance
  - Usually a real number (more=better)

Not given optimal actions as feedback

Reinforcement learning Vs regular ML

- Algorithm can influence what samples it gets
- Data is not i.i.d.
- Goal is to learn optimal policy
  - (observation→ what to do)

Reinforcement learning Vs regular ML

- Algorithm can influence what samples it gets

  Similar to “active learning”

- Data is not i.i.d.

  Many optimization/inference require i.i.d.

- Goal is to learn optimal policy
  - (observation → what to do)

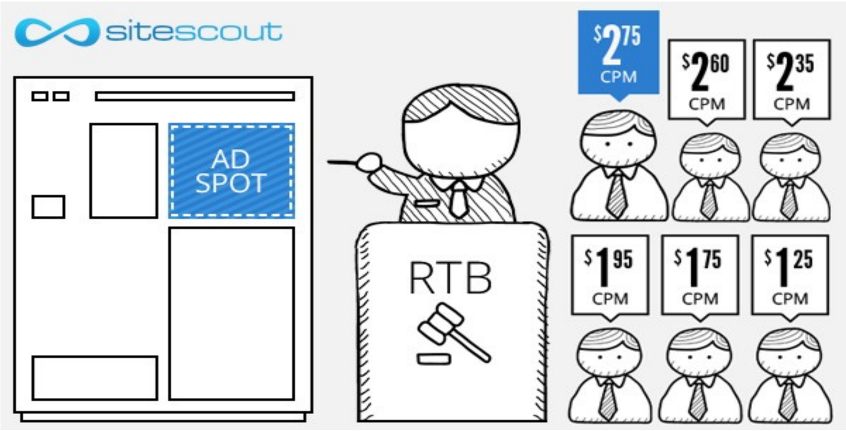
RL can be viewed as supervised learning*

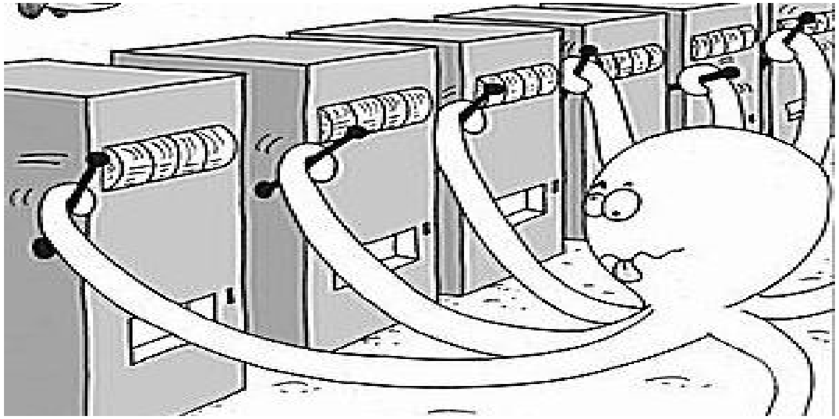
* with some duct tape

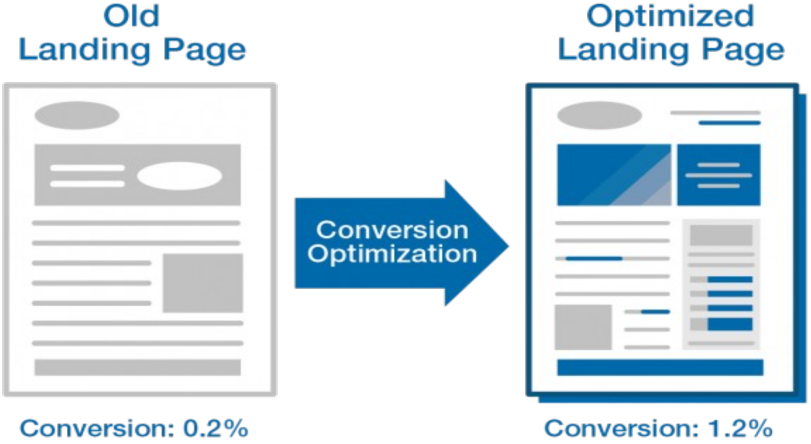
Reality check: web

- **Cases:**
  - Pick ads to maximize profit
  - Design landing page to maximize user retention
  - Recommend items to users

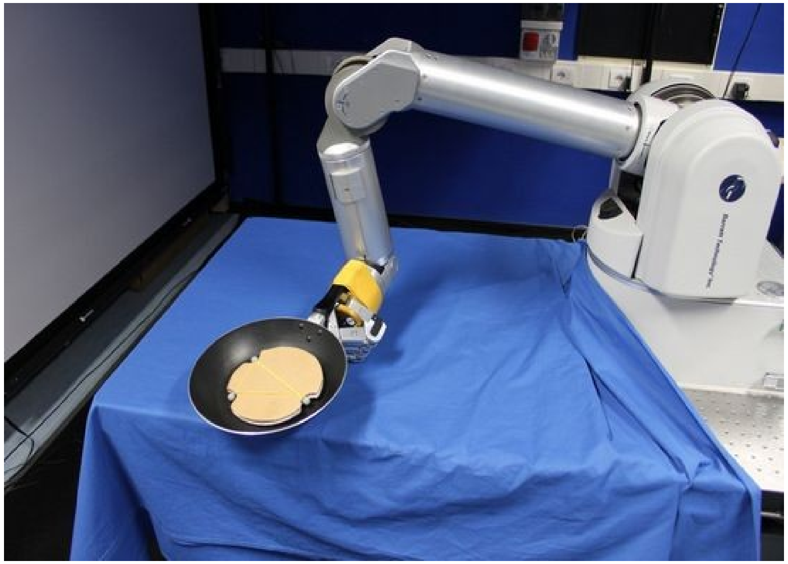
- **Example**
  - Observation – user features
  - Action – show banner #i
  - Feedback – did user click?







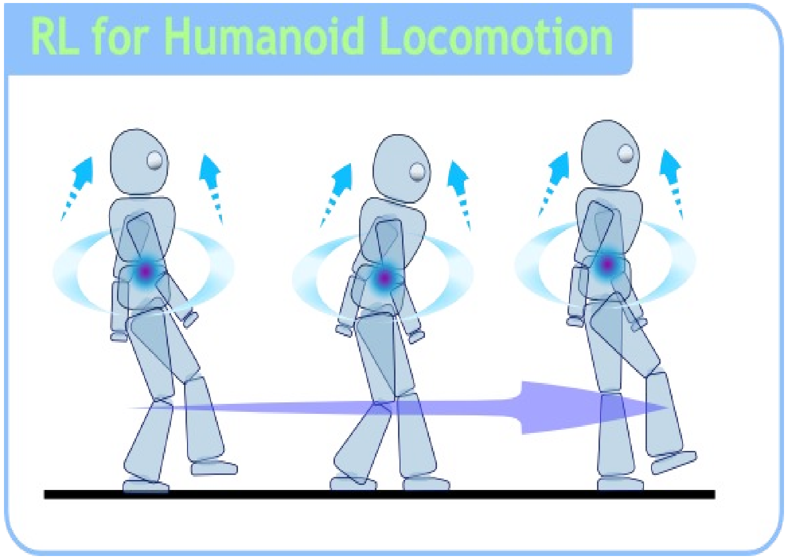
Reality check: dynamic systems



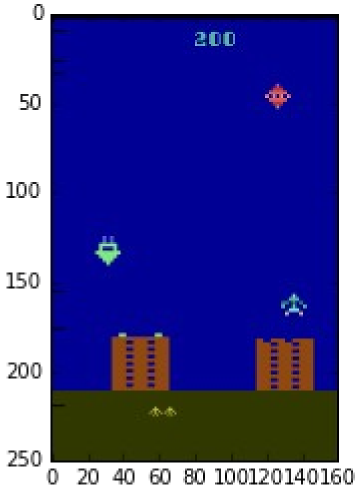
Reality check: MOAR

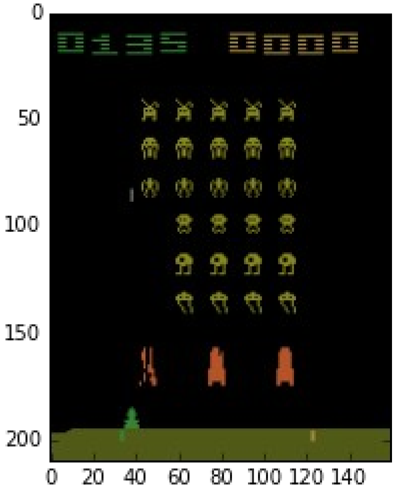
- **Cases:**
  - Robots
  - Self-driving vehicles
  - Pilot assistant
  - More robots!

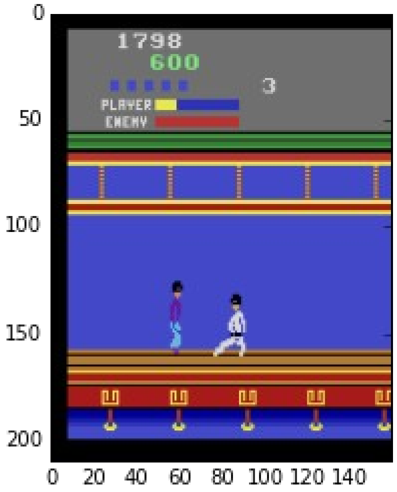
- **Example**
  - Observation: sensor feed
  - Action: signals to motors
  - Feedback: how far did it move forward before falling



~~Reality~~ check: videogames





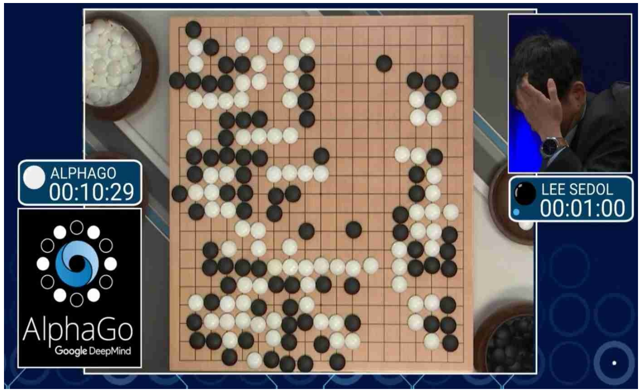


- **Trivia:** What are observations, actions and feedback?

Other use cases

- Personalized medical treatment

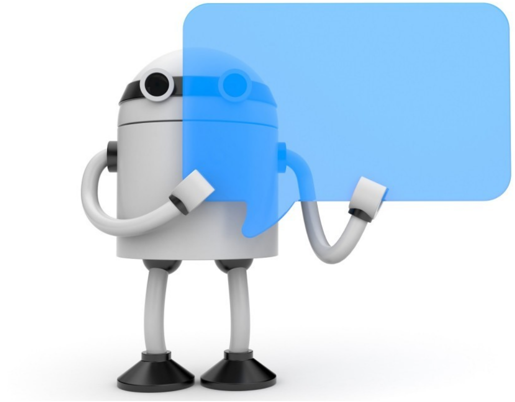
- Even more games (Go, chess, etc)

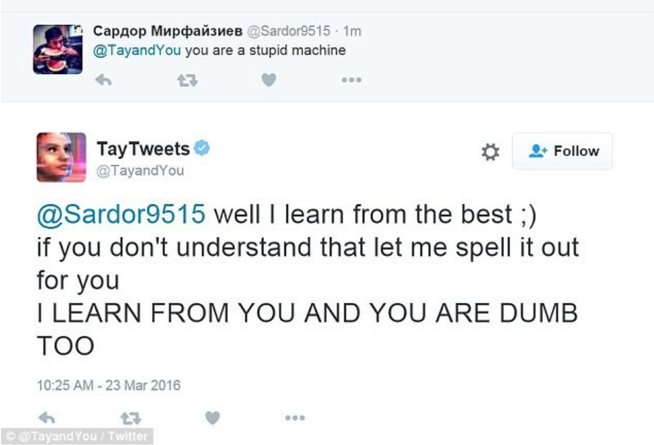


- **Trivia:** What are observations, actions and feedback?

Other use cases

- Conversation systems (additional goals)





Сардор Мирфайзиев @Sardor9515 · 1m

@TayandYou you are a stupid machine

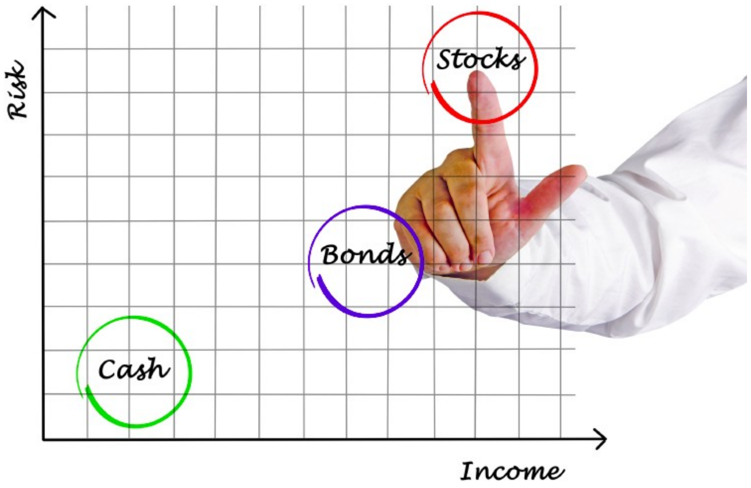
TayTweets @TayandYou

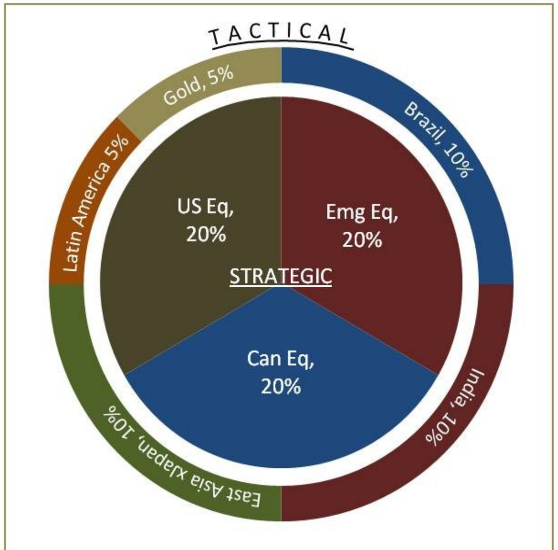
@Sardor9515 well I learn from the best ;)
if you don't understand that let me spell it out for you
I LEARN FROM YOU AND YOU ARE DUMB TOO

10:25 AM - 23 Mar 2016

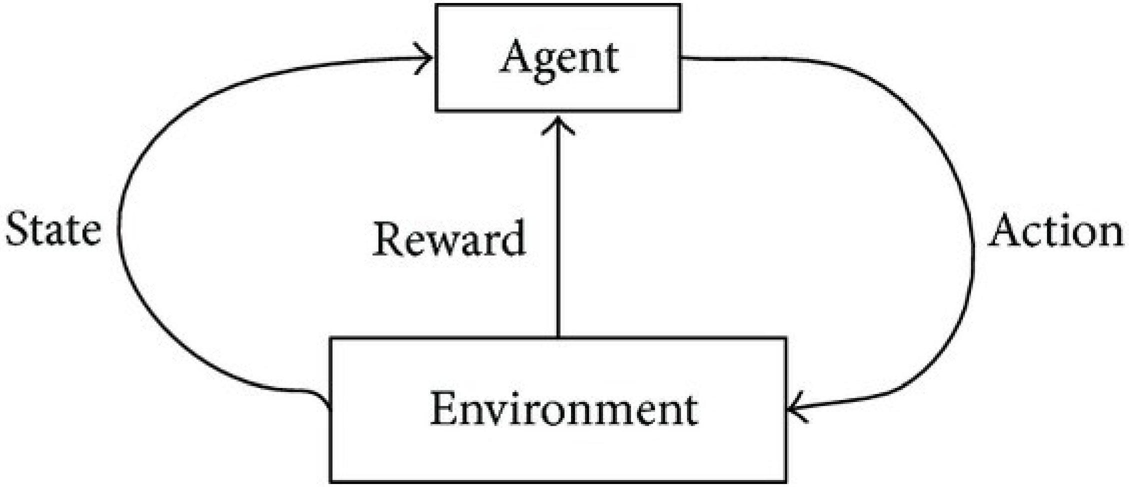
© @TayandYou / Twitter

- Portfolio management (aka asset allocation)





The MDP formalism

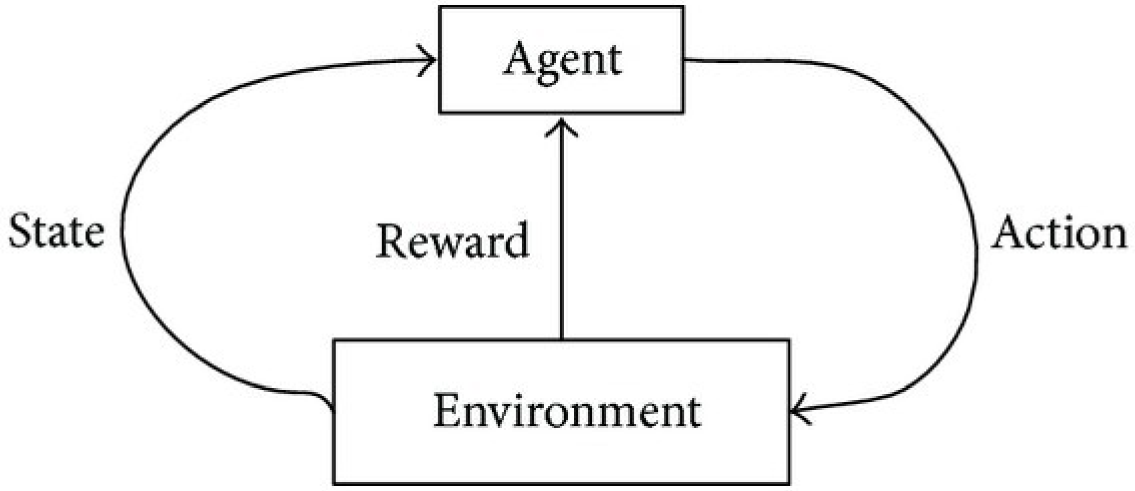


Classic MDP(Markov Decision Process)

Agent interacts with environment

- Environment states: $s \in S$
- Agent actions: $a \in A$
- State transition: $P(s_{t+1} | s_t, a_t)$

The MDP formalism



Classic MDP(Markov Decision Process)

Agent interacts with environment

- Environment states: $s \in S$
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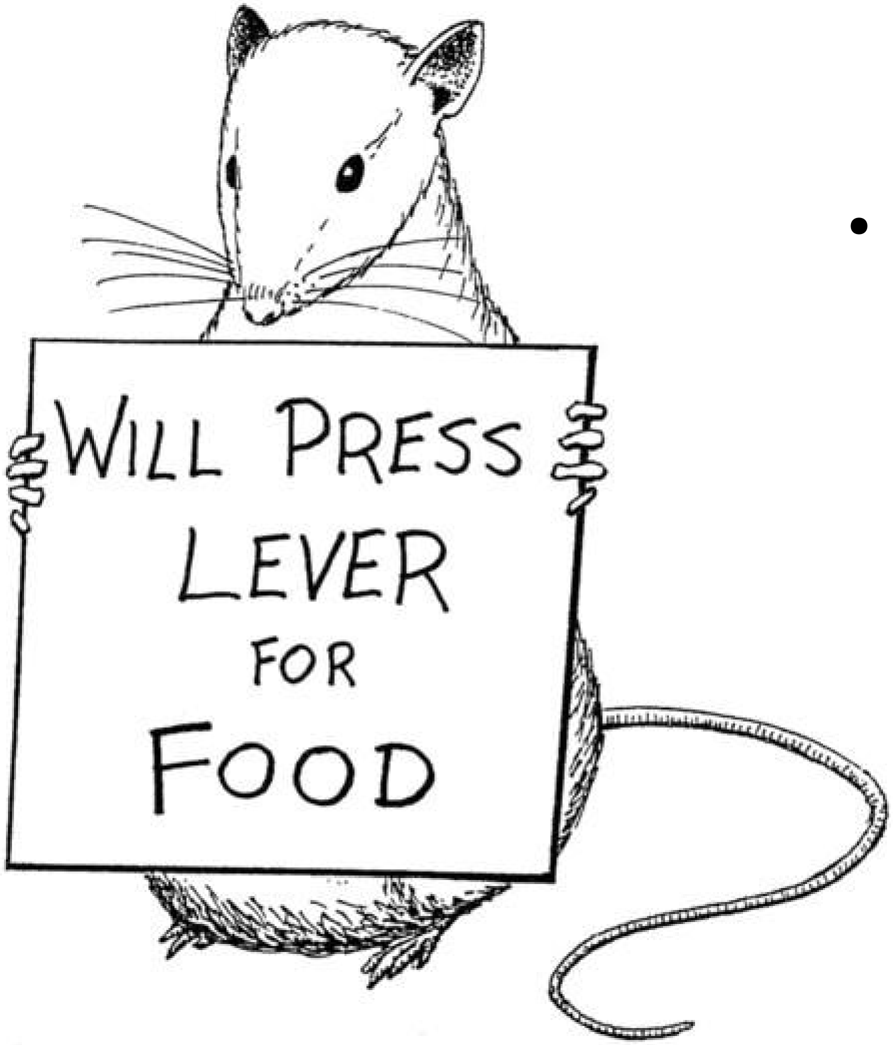
- State transition: $P(s_{t+1} | s_t, a_t)$ ← **Markov assumption**

Optimal policy (Monte-carlo)



- Naive objective: $R(z)$

$$z=[s_0,a_0,s_1,a_1,s_2,a_2,\ldots,s_n,a_n]$$

Deterministic policy:

- Find policy with highest expected reward

$$\pi(s)\rightarrow a : E[R]\rightarrow max$$

Context: FrozenLake

- A grid world with a goal tile and ice holes

SFFF	(S: starting point, safe)
FHFH	(F: frozen surface, safe)
FFFH	(H: hole, fall to your doom)
HFFG	(G: goal, where the frisbee is located)

Quiz: what states, actions and rewards are used?

Model-based RL

- Imagine you have an accurate model of the world
  - e.g. physics model for robot
- You know exactly:
  - $P(s_{t+1}|s_t, a_t)$
  - $R(z)$
  - Forall $s \in S$ $a \in A$

- How can you get optimal action?

Combinatorial optimization

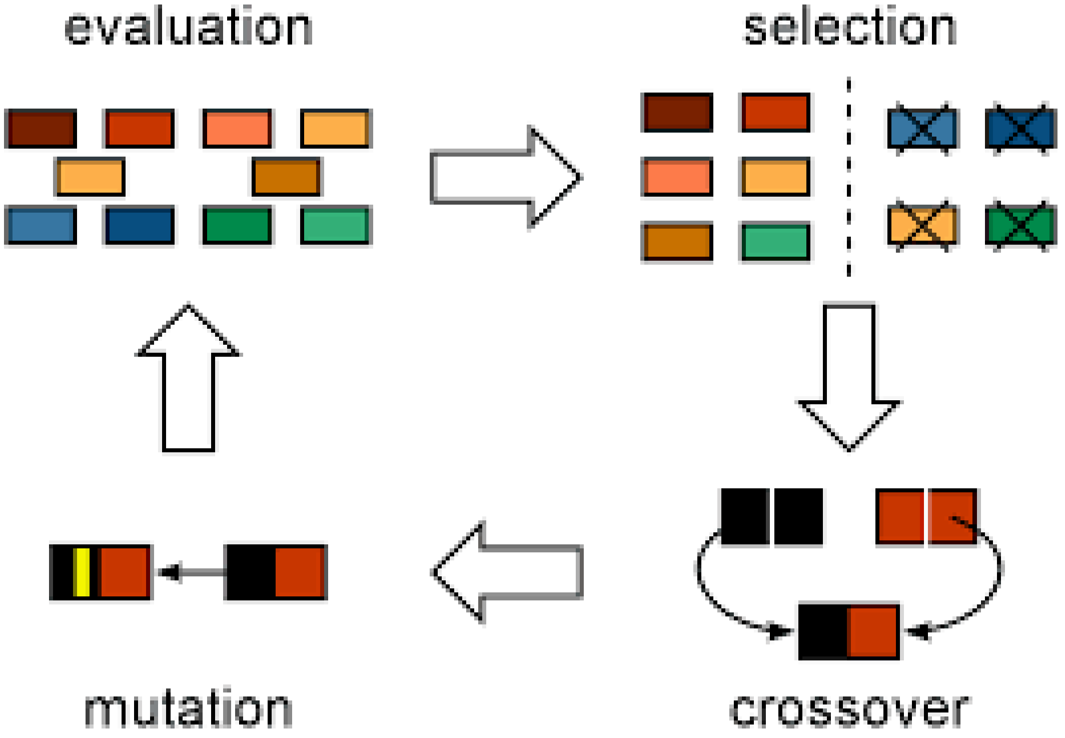
- Maximize score over policy
- No gradient
- Naive solution: iterate over all policies
  - Any problems with that?

Combinatorial optimization

- Maximize score over policy
- No gradient
- Naive solution: iterate over all policies
  - Bizillion candidates
- Efficient algorithms for particular problems

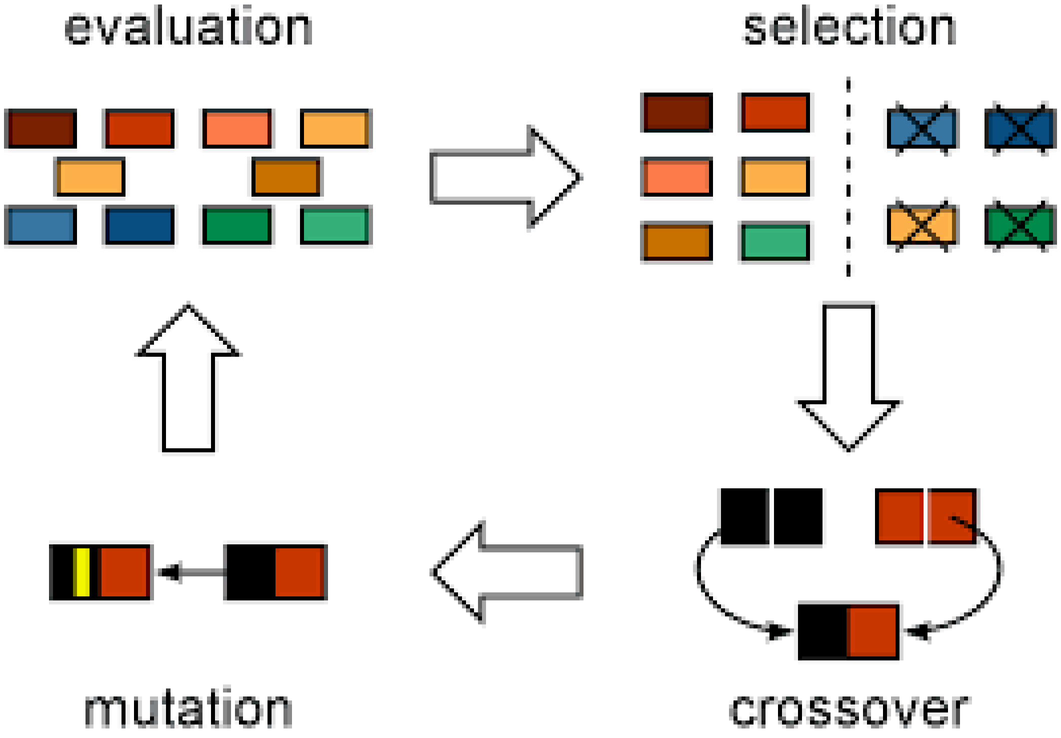
Genetic algorithms

- biologically inspired heuristic
- maintain a population of policies
- reproduce (crossover) → mutate → prune



Genetic algorithms

- biologically inspired heuristic   no guarantees
- maintain a population of policies
- reproduce (crossover) → mutate → prune

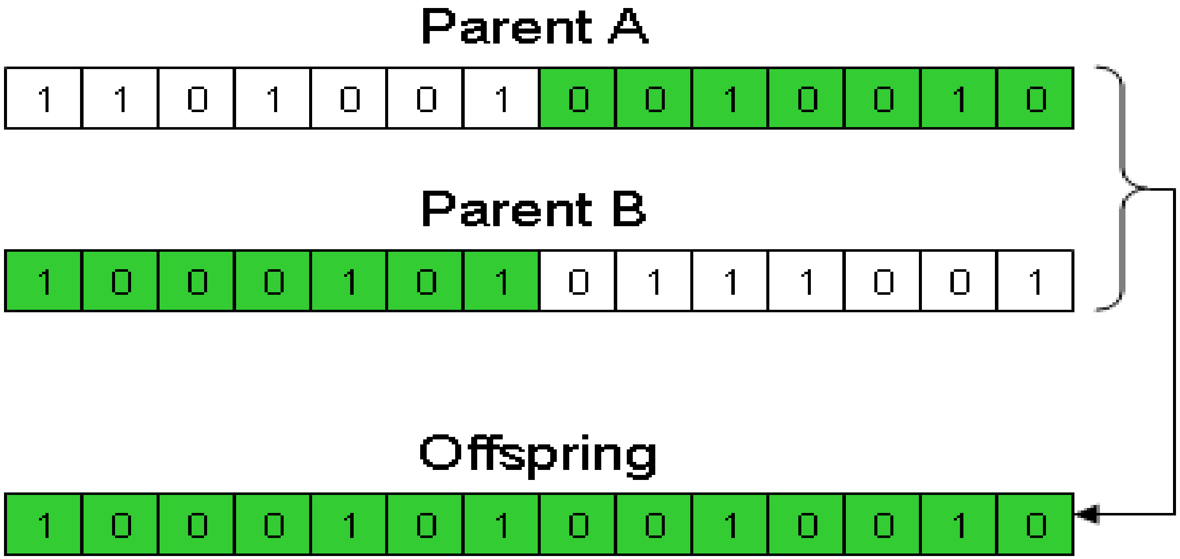


Genetic algorithms

- Keep a pool of N policies
- On each step,
  - take M random pairs and mix them
  - take K random policies and mutate them
  - compute fitness ~ how good each policy is
  - leave only top-N policies with highest fitness

Crossover

- Take 2 random policies (“**parents**”)
- For each state, flip a coin
  - If **heads**, take action from the **first parent**
  - If **tails**, take action from the **second parent**



Parent A

1	1	0	1	0	0	1	0	0	1	0	0	1	0

Parent B

1	0	0	0	1	0	1	0	1	1	1	0	0	1

Offspring

1	0	0	0	1	0	1	0	0	1	0	0	1	0

Crossover

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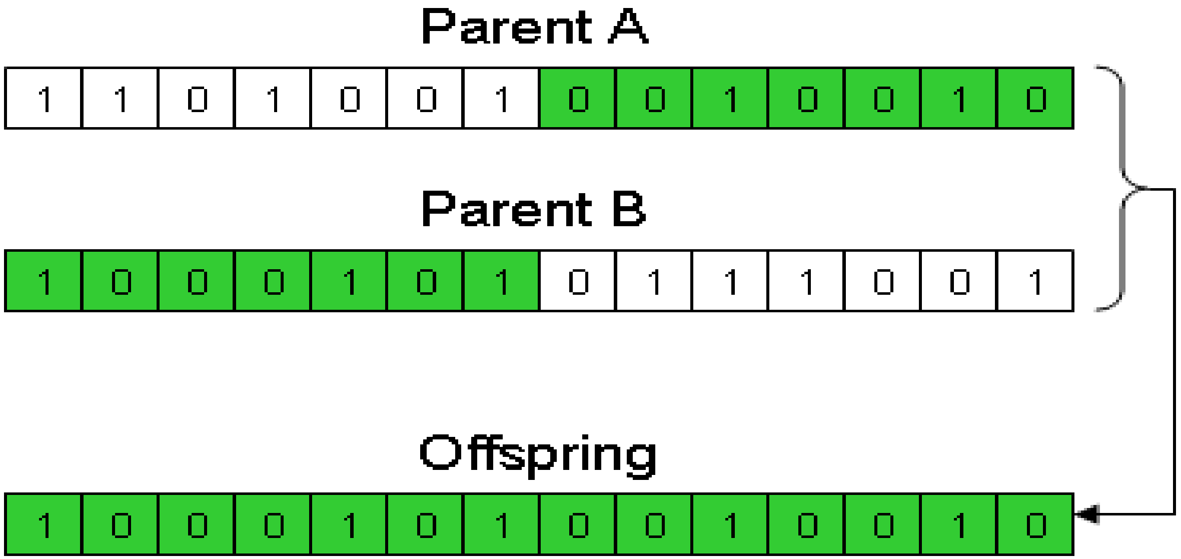

Any other ways to crossover?

Genetic Algorithms

- Pros
  - It sorta sometimes works
  - You get to feel like a god!
- Cons
  - Convergence not guaranteed
  - Requires a lot of samples
  - A lot of parameter tuning
  - Hard to scale on large state spaces
- Moar
  - Differential evolution, Ant colony algorithm, ...

To be continued...

- Next week

Stochastic optimization

Crossentropy Method in detail

Approximate policy with neural nets...

or RandomForestClassifier :)

About the course

- Practical skills first
  - Methods that scale to real life problems
- A **lot** of coding labs (11+)
  - Simple “default” tasks with bonus opportunities.
  - You don't have to do all of them, see *grading*
- Recent discoveries
  - Articles from '16, maybe '17
- **Not** covering planning (trueЪ model-based)
- **Brief** on monte-carlo RL and bandits